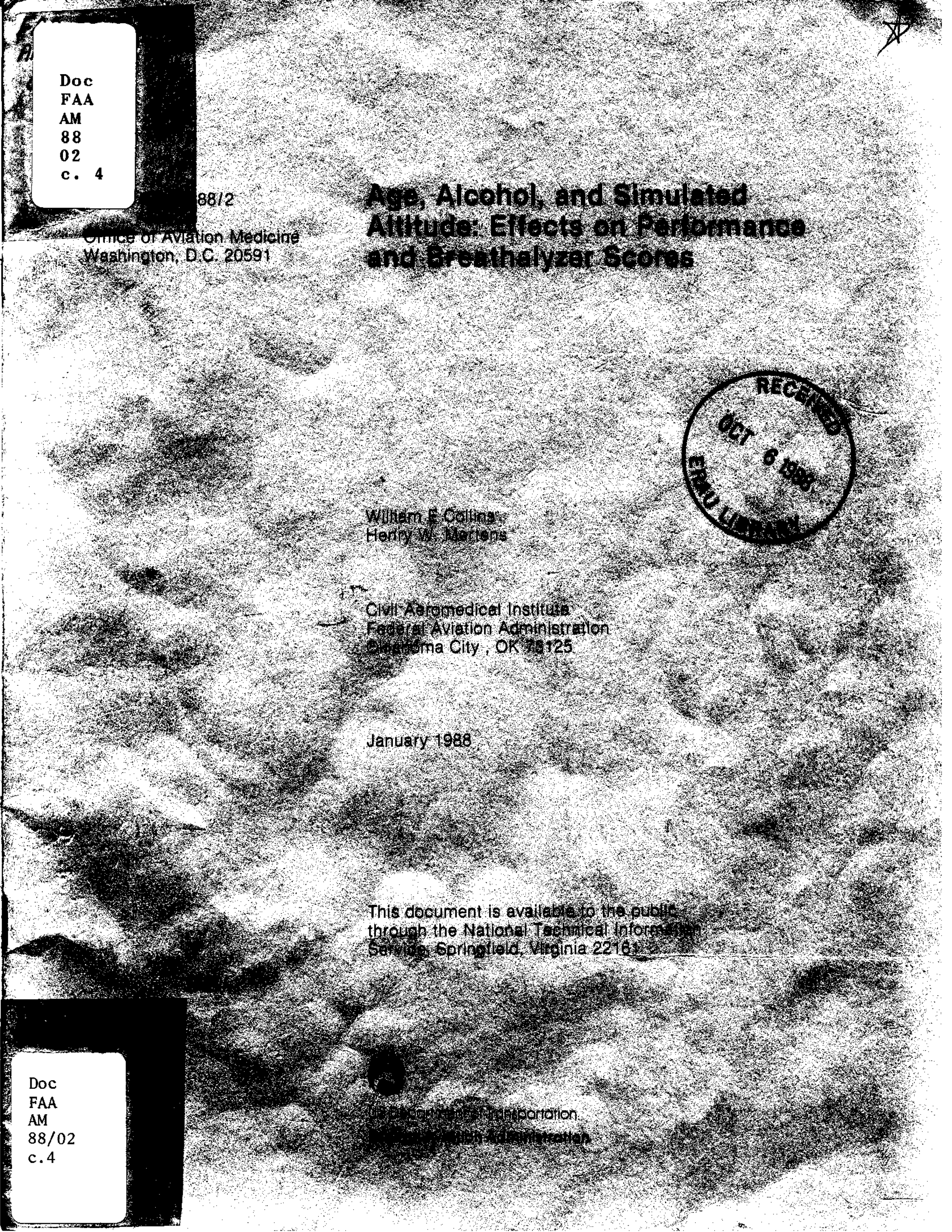

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Age, Alcohol, and Simulated Altitude: Effects on Performance and Breathalyzer Scores

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16. Abstract

Trained men in two age groups, 30-39 (n=12) and 60-69 (n=13), each performed at the Multiple Task Performance Battery (MTPB) in four separate full-day sessions with and without alcohol (2.2 mL of 100-proof vodka per kg of body weight) at ground level and at a simulated altitude of 12,500 ft (3810 m). Subjects breathed appropriate gas mixtures through oxygen masks at both ground level and altitude. Mean breathalyzer readings peaked near 88 mg % and did not differ between age groups or altitude conditions. Younger subjects performed better than older subjects; performance of both age groups was significantly impaired by alcohol, but these adverse effects were greater for the older subjects. No significant effects on performance were obtained due to altitude or to the interaction of altitude with alcohol. These results and those from several other studies suggest that prevalent views regarding the nature of the combined effects of alcohol and altitude on blood alcohol levels and on performance need to be redefined.

17. Key Words
Age, Alcohol, Altitude, Performance

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AGE, ALCOHOL, AND SIMULATED ALTITUDE:
EFFECTS ON PERFORMANCE AND BREATHALYZER SCORES

Previous research in this laboratory yielded no significant interactive effects of alcohol and a simulated altitude of 12,500 feet on either breathalyzer levels or on complex performance (4). That outcome was contrary to prevalent beliefs based on early work by McFarland and his associates (14,15). The present study provided an opportunity to replicate those findings and to add new information concerning the possible effects of age as a factor in the alcohol-altitude-performance equation.

METHOD

Subjects. Twenty-five men, 12 in a 30- to 39-yr age group and 13 in a 60- to 69-yr age group, were subjects. Physiological condition and intellectual ability were controlled by requiring that subjects pass the equivalent of a Class III airman physical examination, exhibit normal pulmonary function, and have an intelligence quotient of normal or above as based on two subtests of the Wechsler Adult Intelligence Scale.

Multiple Task Performance Battery (MTPB). In the Civil Aeromedical Institute's (CAMI) version of the MTPB, five subjects can be run independently at the same time. The MTPB tasks are presented in various combinations to produce a synthetic work situation involving variation of workload and time sharing of work in assorted tasks. Each subject works at a console that incorporates the following tasks:

Monitoring of warning lights. These are choice reaction-time tasks involving monitoring of five green lights (normally on) and five red lights (normally off). Subjects pushed the light/switch whenever a light changed state. Response times were recorded.

Monitoring of meters. The pointers of four meters constantly moved at random about the center position. Subjects responded to a shift in mean position of a pointer to the left or right of center by pushing a button under the meter on the side of the deflection. Response times were scored.

Mental arithmetic. Subjects were required to add two 2-digit numbers presented on a console screen and then mentally subtract a third number from the sum; answers were recorded with a 10-key pad. Response time and accuracy were assessed.

Pattern identification. A standard histogram pattern was displayed on a 6 x 6 cell matrix for 5 s and followed by successive presentations of two comparison patterns for 3 s each, with 2-s intervals between patterns. Subjects pressed an appropriate response button if one, neither, or both of the comparison patterns matched the standard pattern. Response latency and accuracy were recorded.

Tracking. The display for the two-dimensional compensatory tracking task was an oscilloscope screen. A varying amplitude was imparted in each dimension to a green dot target; the subject counteracted the disturbance to keep the dot at screen's center by moving a control stick. Performance was measured in mean vector absolute error and mean vector root mean square error.

Problem solving. Subjects had to discover the correct sequence in which to press five response buttons, using a trial-and-error process with a left-to-right search procedure. Pressing a button in incorrect order caused a red light to turn on and stay on until the next correct response was made. Pushing all five buttons in correct order caused a blue light to turn on. After a problem was solved, the same problem was re-presented after a lapse of 15 s; the subject had to reenter the previous solution from memory on this confirmation presentation. Performance measures were: (i) mean response latencies for the first solution and confirmation stage and (ii) the mean number of errors per problem made during the confirmation stage.

MTPB Workloads. MTPB tasks were always administered in a basic 1-h schedule that involved five 10-min intervals of work under various combinations of MTPB tasks followed by a 10-min rest period. All five workload intervals involved monitoring of red and green warning lights and meters. The first 10-min MTPB interval (low workload) included tracking in addition to monitoring. The second interval (moderate workload) involved mental arithmetic, problem solving, and monitoring. The third interval (moderate workload) involved problem solving, tracking, and monitoring. The fourth interval (high workload) involved problem solving, target identification, and monitoring. The fifth 10-min interval (high workload) included mental arithmetic, pattern identification, and tracking, in addition to monitoring.

Performance was assessed in terms of composite scores for each task. Composite scores summarized all measures of performance for the particular task. An overall composite score (all tasks) was also obtained, as well as a composite score for the three monitoring tasks (red lights, green lights, meters) and a composite score for the four "active" tasks (mental arithmetic, pattern identification, tracking, problem solving), which involved greater demand on cognitive resources. Composite scores for individual tasks were calculated as follows: For each measure of performance on a task, the raw scores for all subjects were converted to standard scores with a mean of 500 and a standard deviation of 100. The task composite score for each subject and experimental treatment was the mean of standard scores on each performance measurement for that task. The sign of scores was changed, when necessary, so that higher standard scores always indicated better performance, and lower scores, poorer performance. Overall, monitoring and active composite scores were computed by averaging the appropriate task composite scores for each subject and treatment so that each task made an equal contribution to the variance. These composite scores are more sensitive to the effects of experimental conditions than are individual measurements of performance.

Breathalyzer. Breath alcohol levels were assessed by means of an Omicron Intoxilyzer. Practice at using the device was provided the subjects during performance training. Subjects learned to take a deep breath, remove the oxygen mask, and breathe into the breath-recording device.

Procedure. Following 21 h of training on the MTPB, subjects participated in four experimental test sessions spread over a two-wk period with at least two days between sessions. Subjects were tested in groups of 3-5, with members of each age category in each group tested. The four test conditions included the four possible combinations of the two altitude and two drug conditions. The altitude conditions were 12,500 ft (3,810 m) or ground level (approximately 396 m). Altitude simulation was accomplished by gas mixtures (13.5% oxygen and 86.5% nitrogen) administered through face masks worn by subjects. These mixtures were verified by analyses with a model MGA-1100, Perken-Elmer Medical Gas Analyzer. Compressed air was used for the ground level condition.

Subjects drank equal volumes of either a placebo or an alcoholic drink at the start of each session. Alcohol doses were 2.2 mL of 100-proof vodka per kg of body weight mixed with three parts of either tomato or orange juice, as selected by the subjects. The placebo drink contained a few drops of rum extract floated on top of ice cubes primarily to produce the odor of an alcoholic beverage. Subjects consumed each drink in a 20-min period; testing began 30 min after drinking was completed.

In all four experimental conditions, the morning MTPB performance session began at 0900 and involved three repetitions of the basic 1-h work schedule, ending at 1200. After a lunch break, the afternoon session began at 1300 and involved a similar schedule. During every morning and afternoon session, subjects breathed the appropriate gas mixture for the entire 3-h duration. Mood rating scales were administered before the morning performance session and after both morning and afternoon sessions. Subjects rated mood, on nine-point scales, regarding levels of attentiveness, tiredness, boredom, tenseness, and irritation (18).

RESULTS

Breathalyzer. Mean breathalyzer readings peaked around 88 mg % and did not differ between age groups or altitude conditions (see Fig. 1).

MTPB _Performance_. Mean performance scores for each of the seven individual tasks of the MTPB and for the three types of composite scores (i.e., overall, monitoring, and active tasks) are presented in Table 1 for the four conditions and the two age groups. Overall composite score means (all seven tasks combined) were also calculated separately for the two age groups by successive work hours for each of the four drug/placebo conditions (see Fig. 2). The best performance for both age groups occurred under the placebo conditions; there were no differences in placebo scores for ground level vs. altitude. Alcohol depressed scores for both age groups, but more so for the older group; again, there were no differences in scores between ground level and altitude (see Fig. 2).

Analyses of variance (see Table 2) of the Overall Composite Scores (all tasks) indicated significant ($p < .001$) differences in performance favoring the younger age group, and favoring placebo over alcohol conditions; performance during later time periods was significantly ($p < .05$) better than early work hours (due to alcohol effects). Only three interactions were significant: age group x time ($p < .05$), drug x time ($p < .001$), and age group x drug x time ($p < .05$). These interaction effects are apparent in analysis of Fig. 2 and are related to the fact that alcohol more strongly depressed older

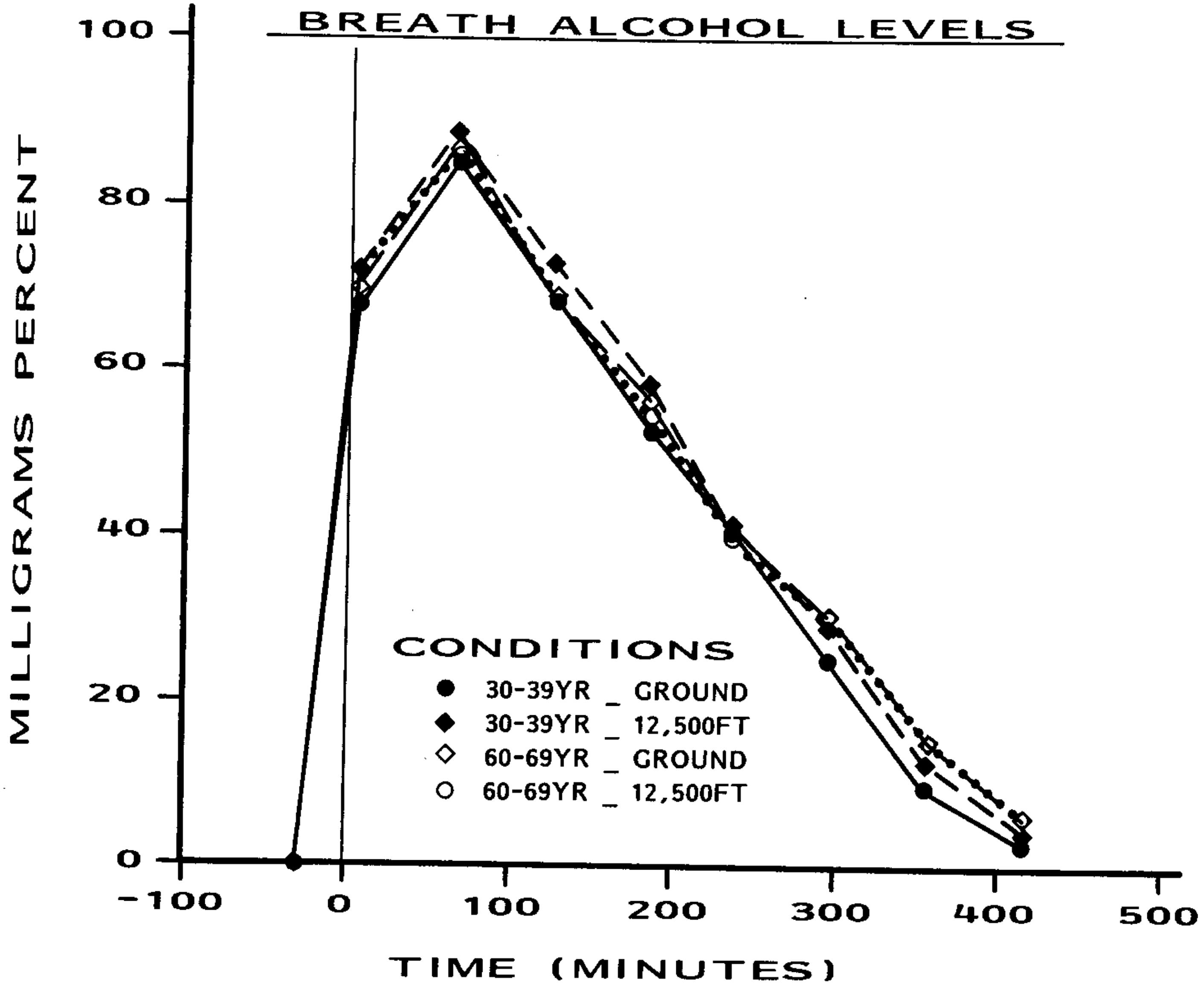

FIGURE 1. MEAN BREATH ALCOHOL LEVELS OBTAINED BEFORE AND DURING 7-HOUR TESTING SESSIONS FROM GROUPS OF YOUNGER AND OLDER SUBJECTS AT GROUND LEVEL AND AT A SIMULATED ALTITUDE OF 12,500 FT.

Table 1.-Standard MTPB Scores (Means and Standard Deviations) for Composite and Individual Task Measures as a Function of Age Groups, Drug (alcohol vs. placebo), and Altitude (ground vs. 12,500 ft).

Measures		30-39 yr group				60-69 yr group			
		Placebo		Alcohol		Placebo		Alcohol	
Composite		Gnd	Alt	Gnd	Alt	Gnd	Alt	Gnd	Alt
Overall Composite	Mean	534	537	518	516	487	490	465	461
	S.D.	30	26	38	46	33	30	43	45
Monitoring Composite	Mean	533	540	523	523	486	485	466	454
	S.D.	30	28	41	46	44	43	46	55
Active Tasks Composite	Mean	534	536	514	510	488	494	465	466
	S.D.	33	30	45	52	36	32	52	49
Individual Task									
Green Lights	Mean	556	551	540	534	474	475	442	441
	S.D.	35	39	43	51	74	65	69	65
Red Lights	Mean	513	530	502	523	489	497	479	472
	S.D.	75	52	79	55	48	51	48	61
Meters	Mean	530	538	526	512	493	482	477	450
	S.D.	35	17	36	74	56	62	68	107
Tracking	Mean	539	533	523	507	480	486	470	469
	S.D.	59	67	75	51	43	53	47	48
Arithmetic	Mean	532	537	523	517	488	491	456	464
	S.D.	33	41	43	43	47	44	81	72
Pattern Ident.	Mean	525	533	483	488	510	517	480	467
	S.D.	47	42	102	120	62	43	85	92
Problem Solving	Mean	541	540	527	528	476	484	453	461
	S.D.	46	46	60	57	46	34	78	56

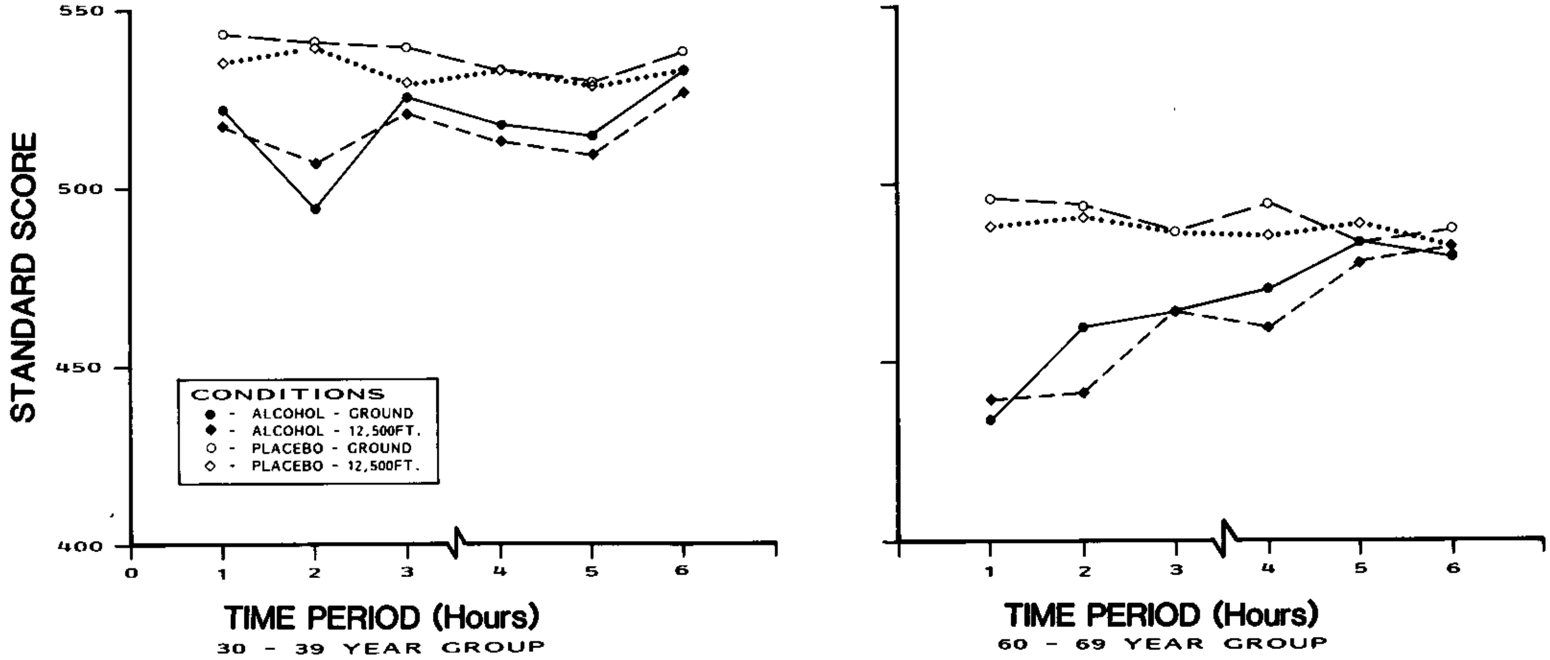

FIGURE 2. MEAN OVERALL COMPOSITE SCORES FROM MTPB PERFORMANCE BY GROUPS OF YOUNGER AND OLDER SUBJECTS AT GROUND LEVEL AND AT A SIMULATED ALTITUDE OF 12,500 FT FOR 6 HOURLY WORK PERIODS (A 1-HR LUNCH BREAK PRECEDED THE FOURTH WORK PERIOD).

subjects' scores, particularly during the three time periods that comprised the morning session. There was no interactive effect of alcohol and altitude.

TABLE 2.-Results of analyses of variance conducted separately for the overall composite scores and the composite scores for the four active tasks (mental arithmetic, pattern identification, tracking, problem solving) and for the three monitoring tasks (meters, red and green lights). Levels of statistical significance for all main effects are presented along with interactions that proved significant. All other (unlisted) interaction terms yielded no significant effect for any of the comparisons.

	COMPOSITE SCORES		
All Main Effects	Overall	Active Tasks	Monitoring Tasks
Age Group (Ag)	.001	.001	.001
Drug (D)	.001	.001	.001
Altitude (Al)			
Time (T)	.05	.05	
Workload (W)	N/A	N/A	.001
Only Significant Interactions			
Ag x T	.05	.01	
D x T	.001	.001	.01
Ag x W	N/A	N/A	.001
Ag x D x T	.05		.01

Separate analyses were conducted to assess the effects of the experimental conditions on (i) composite scores for monitoring performance (red lights, green lights, and meters; the three tasks common to all workload conditions) and (ii) composite scores for the four active tasks (mental arithmetic, pattern identification, tracking, problem solving). The latter yielded results almost identical to that obtained for the overall composite scores with the exception that the 3-way interaction (age group x drug x time) was not significant (see Table 2). The monitoring tasks analysis, the only type of composite score analysis to include the variable of "workload", showed the familiar significant ($p < .001$) main effects of age (favoring the younger group) and drug (favoring the placebo) as well as that of workload (favoring

Table 3.-Results of Analyses of Variance Conducted Separately for the Seven Individual Tasks of the Multiple Task Performance Battery. Levels of statistical significance for all main effects are presented along with interactions that proved significant. All other (unlisted) interaction terms yielded no significant effect for any of the comparisons.

	Individual Tasks						
ALL MAIN EFFECTS	LIGHTS GREEN	LIGHTS RED	METERS	ARITHMETIC	PATTERN IDENT	PROB SOLV	TRACKING
Age Group (Ag)	.001	.05	.01	.01		.001	.05
Drug (D)	.001	.01	.001	.001	.001	.001	.001
Altitude (Al)							
Time (T)	.001			.001	.05	.01	
Workload (W)	.001	.001	.001	.001		.001	.001
Only Significant Interactions							
Ag x T				.001			
Ag x W	.01	.01	.001				
D x T	.001		.05	.001	.001	.01	.01
D x W					.01	.05	
T x W		.01		.05			.001
Ag x D x T		.05		.001		.05	
Ag x Al x W	.05						
Ag x T x W			.05				
Al x T x		.05					
Ag x D x Al x W		.05					
Ag x D x T x W		.05					

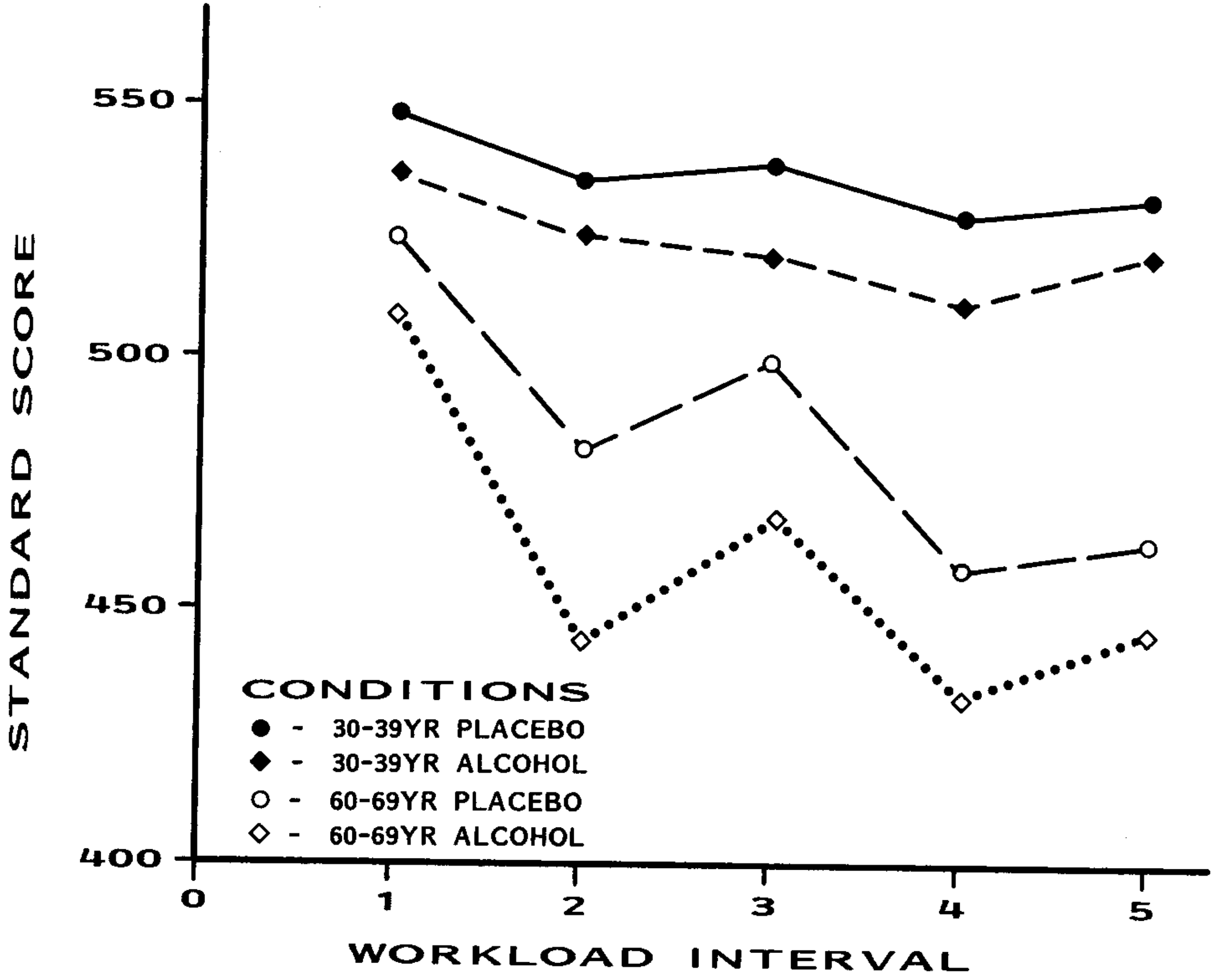

FIGURE 3. MEAN MONITORING COMPOSITE SCORES FROM MTPB PERFORMANCE AS A FUNCTION OF WORKLOAD, AGE OF SUBJECTS, AND DRUG CONDITION (ALCOHOL OR PLACEBO).

Table 4.-Rating Scores (Means and Standard Deviations) for each of the Five Mood Factors on the Subjective Rating Scale and Results of Separate Analyses of Variance of Each Mood Factor for the Main Effects of Age Group, Drug, Altitude, and Time.

Rating Scale		Age Group		Drug		Altitude		Time		
		30-39	60-69	Placebo	Alcohol	Gnd	Alt	0900	1200	1600
Attentiveness	Mean	5.3	5.5	5.6	5.2**	5.3	5.4	5.8	5.3	5.1**
	S.D.	1.5	1.5	1.5	1.4	1.4	1.5	1.4	1.5	1.4
Tiredness	Mean	5.6	5.1*	5.0	5.8***	5.3	5.4	4.5	5.6	6.0***
	S.D.	1.4	1.7	1.6	1.4	1.5	1.6	1.6	1.2	1.3
Tenseness	Mean	4.3	4.3	4.2	4.4	4.3	4.3	3.9	4.3	4.8***
	S.D.	1.6	1.4	1.5	1.5	1.5	1.6	1.4	1.5	1.6
Boredom	Mean	4.7	3.5**	3.8	4.3**	4.1	4.0	3.5	4.1	4.6***
	S.D.	1.6	1.7	1.7	1.7	1.7	1.8	1.5	1.7	1.9
Irritation	Mean	2.1	1.8	1.8	2.1*	2.0	1.9	1.4	1.9	2.5***
	S.D.	1.5	1.2	1.1	1.5	1.3	1.4	0.9	1.3	1.6

* $p<0.05$ ** $p>0.01$ *** $p>0.001$

There were only five interactions significant (all at the $p< 0.05$ level) from the ANOVAs. They were: for attentiveness, age group x altitude x time and drug x altitude x time; for tenseness, age group x time; for boredom, drug x altitude; and for irritation, drug x time.

lighter workloads) and the interaction of age group x workload ($p < .001$) (favoring the younger group and lighter workloads); in addition, both alcohol x time period and age group x alcohol x time period (favoring the placebo condition, younger subjects, and later time periods) were significant ($p < .01$). No significant main effects of altitude or interaction of altitude with any other variable was obtained.

Scores for the individual tasks were subjected to separate analyses (see Table 3) and yielded results that were similar to the analyses of composite scores. Each task showed a significant ($p<.01-.001$) negative effect of alcohol, but no individual task showed an effect of altitude or of an altitude/alcohol interaction. There were significant ($p<.05-.001$) main effects of age group (favoring the younger subjects) and of workload (favoring lighter workloads) on scores for each individual task except pattern identification. Time periods showed significant ($p<.05-.001$) differences for the monitoring of green lights and for arithmetic, pattern identification, and problem solving, but not for the monitoring of red lights or of meters, or for tracking.

Workload had a significant main effect in almost all tasks, as noted above. Subjects tend to give the three monitoring tasks lower priority compared with other MTPB tasks that require more active participation. The monitoring tasks, therefore, generally have secondary status and provide an index of residual attention that is related to workload. Fig. 3 illustrates how monitoring performance varied as a function of age, alcohol, and workload. The pattern of monitoring performance in Fig. 3 indicates that task demands (workload) were highest (and monitoring performance lowest) in workload interval 4, with workload intervals 5, 2, 3, and 1 following in that order. The interaction of age group with workload was statistically significant ($p <.001$) for the monitoring composite scores as well as for the three individual monitoring tasks, but there was no other interaction of workload in monitoring composite scores with any other task. A slight tendency for alcohol effects on monitoring performance to be greatest at higher workload was not statistically significant.

<u>Mood Ratings</u>. Mean ratings for attentiveness, energy, tenseness, boredom, and annoyance are presented in Table 4. Mood results generally did not parallel performance findings. For all five moods there was a significant ($p < .01-.001$) effect of time periods, the result of successively poorer mood scores from the first through the third measurement period, irrespective of the drug or altitude conditions. For all mood ratings except "tenseness" there was a significant effect of alcohol ($p < .05-.001$); these significantly poorer scores for the alcohol (vs. placebo) condition were the only findings common to both the performance and mood data. For "tiredness" and "boredom" there was a significant age group effect ($p < .05-.01$), favoring the older subjects (who were less tired and less bored). Only five of the 55 interactions yielded significant effects (all at $p < .05$): for "tenseness", (age group x time period); for "irritation", drug x time period; for "boredom", drug x altitude; and for "attentiveness", altitude x time x age group and altitude x time x drug.

DISCUSSION

★<u>Age</u>. The older subjects performed significantly more poorly than did the 30-39 year olds on all composite measures of performance and on all the individual tasks except pattern identification. The older subjects also showed more performance impairment at the higher levels of workload than did the younger group. Alcohol ingestion resulted in significant performance impairment for both age groups, but the 60-69 year age group was more negatively affected; performance for both groups appeared to show full recovery by the sixth postingestion hour. Altitude had no deleterious effect on performance either as a separate main effect or as an interaction with alcohol. Mood scores differed between the age groups only for "tiredness" and "boredom"; in both cases the scores favored the older subjects (i.e., they reported being less tired and less bored).

Alcohol. The ingestion of alcohol resulted in significant impairment for scores on all individual tasks and MTPB composites. That impairment persisted for several hours with all group scores appearing to show full recovery by the 6th postingestion hour. Significant impairment due to alcohol has been demonstrated for other flight-related tasks at blood alcohol levels (BAL's) as low as 30-50 mg % in-flight simulator studies (1,7,8) and at 40 mg % during inflight studies (2). A laboratory study of tracking performance showed performance decrements during angular acceleration, but not when subjects were stationary, at a peak BAL of 27 mg % (6).

Workload. Although significant workload effects were observed in performance in all tasks, the only substantial interaction of workload with other factors was the interaction of age group with workload in monitoring performance. Monitoring performance scores tended to decrease slightly with workload in younger subjects, but large decrements in monitoring scores were observed in the older subjects. The greater sensitivity of older subjects to variations in workload is a common finding in MTPB research.

Alcohol/Altitude Effects. The results from this study share some features in common with five previous experiments from this laboratory, none of which reported any effect of 12,000-12,500 ft (3658-3810 m) altitudes on breath or blood alcohol levels, and none of which found any synergistic interaction of those altitudes and alcohol on performance scores. The findings of those five studies, however, are at some variance with a commonly held view rooted in an authoritative textbook by McFarland (12), wherein he concluded that "...the alcohol in two or three cocktails would have the physiological action of four or five drinks at altitudes of approximately 10,000 to 12,000 ft." Also, "Airmen should be informed that the effects of alcohol are similar to those of oxygen want and that the combined effects on the brain and nervous system are significant at altitudes even as low as 8,000 to 10,000 ft." (And, in a subsequent paper (13), "...the alcohol in two or three cocktails taken at 6-8,000 feet cabin altitude would tend to have the effects of four or five cocktails at sea level.") Those conclusions, based primarily on the results of McFarland's own pioneering studies (14,15) and one by Newman (17), have a physiological basis. Because the oxygen uptake of tissue cells is reduced both by alcohol (histotoxic hypoxia) and in a different way by altitude (hypoxic hypoxia), an interaction, at least additive (13) and perhaps synergistic, of the effects of alcohol and of altitude on performance might be expected.

The major research leading to these conclusions was reported in 1936 by McFarland and Forbes (15), who served as the subjects in unique experiments conducted in the Andes Mountains. Blood alcohol values at two altitudes (12,200 ft and 17,500 ft) rose more rapidly and reached higher levels than did those at sea level. While the impairment of auditory thresholds was greater at high altitudes than at sea level, performance scores on a "dotting" test showed "...a great increase in the variability of responses but the average differences following the alcohol in the mountains compared with sea level were insignificant." Actually, performance scores declined with altitude and with alcohol, but there was no interaction between the altitude and alcohol conditions (compared to sea level, scores were 8% and 12% lower for McFarland at 12,000 and 17,000 ft respectively, before alcohol was ingested; alcohol produced a 20% decrement in performance at sea level and, from that base, scores declined only 6-7% for the two altitude levels). Nevertheless, results from the blood alcohol values (and perhaps the auditory thresholds) pointed to significant altitude-alcohol interactions.

McFarland found additional supporting evidence in his 1936 altitude chamber study with Barach (14). The problem was thoughtfully approached from another perspective: the oxygen want produced by alcoholic intoxication was counteracted by inhalation of excess concentrations of oxygen (50%) and carbon dioxide (2-5%). Subjects exposed to the excess concentration had significantly lower BAL's and lactic acid levels than they did when breathing normal air; subjects given a set of performance tests showed decrements due to alcohol and most showed improvement when breathing the increased oxygen/carbon dioxide. Thus, an increase of oxygen and carbon dioxide appeared to mitigate the effects of alcohol by lowering BAL's and tempering performance decrements.

Finally, McFarland cited the study by Newman (17), in which five subjects performed at a pursuitmeter task in room air and at a simulated altitude of 18,000 ft (by gas mixture, breathed through oxygen masks for a period of about three min around each testing time). Subjects were given alcohol doses every 30 min and were tested before each dose. The experiment was terminated for each subject as soon as his performance score fell five percent below the control series value. For three subjects there was a marked reduction of the blood alcohol concentration at which performance fell significantly when the low-oxygen mixture was breathed; two subjects showed no significant change. "Since the low-oxygen mixture alone produced no lowering of performance, and since the alcohol concentrations at which performance fell off when respiring this mixture produced no such effect when room air was respired, the conclusion is inescapable that the combination of this alcohol concentration and the low oxygen tension produced what neither was able to do alone." Newman (17) noted that effects were unlikely to be obtained at altitudes lower than 18,000 ft.

More recent studies suggest a modified conclusion. Higgins and his associates (9) examined alcohol effects under three altitude chamber conditions: ground level (1287 ft), 12,000 ft, and 20,000 ft (for the latter, a 100% oxygen mixture was provided via a demand-type regulator system). Subjects received 0, 1.25, or 2.00 cc of 100-proof bourbon per kg of body weight. Several physiological measures, BAL's, and performance scores were obtained. There were no differential performance effects; the tests thus were relatively insensitive. At the low alcohol dose, there were no significant BAL differences (peaks were about 37 mg %) among the three altitude conditions; at the higher dose, there were no BAL differences between ground level and the 12,000-ft condition (peak BAL's around 95 mg %), but the 20,000-ft condition yielded a uniformly higher blood alcohol curve with a peak around 118 mg %.

A followup study (10) was conducted in which the ground-level condition was replaced by a chamber altitude of 12,000 ft with supplemental oxygen. The low dose of alcohol again yielded no differences in peak BAL's (around 42 mg %) or in the general coincidence of the BAL time curves. At the higher alcohol dose, the two 12,000-ft conditions (with and without supplemental oxygen) yielded no differences in peak BAL's (around 111 mg %), but the 20,000-ft condition (with supplemental oxygen) yielded a BAL peak around 122 mg %. Clearly, the BAL peaks reached at 12,000 ft (with or without supplemental oxygen) were not different from those produced at ground level. With regard to the 20,000-ft altitude condition, Higgins et al. (10) proposed that increased motility of the gastrointestinal tract caused by the high alcohol concentration combined with increased motility attributable to the lowered barometric pressure at 20,000 ft could increase the absorption rate of the alcohol with the high dose, thereby producing the higher blood alcohol levels.

In an alcohol study that focused primarily on several physiological measures, Lategola, Lyne, and Burr (11) included an arithmetic test in comparison of ground-level performance with that at a chamber altitude of 12,000 ft. The time courses of the BAL curves were virtually identical at ground level and at altitude with peaks about 91 mg %. Arithmetic scores (errors per minute) were impaired by alcohol but did not differ between ground level and altitude following alcohol ingestion (performance was actually slightly better at 12,000 ft).

Collins (3) trained eight pilots to perform on a two-dimensional tracking task (joystick control of a localizer/glideslope instrument) while stationary and during yaw-axis motion. Tracking scores were obtained at ground level and at a simulated altitude of 12,000 ft with a placebo and with alcohol. Subjects performed in the evening, drank until midnight, were retested, slept, and performed the task again in the morning. Ground-level sessions always preceded ascent in the altitude chamber. Following alcohol ingestion (3.25 mL of 100-proof vodka per kg of body weight), peak breath alcohol levels taken at ground level averaged 91 mg %. Alcohol by itself caused performance deterioration, and altitude by itself impaired performance only during the midnight sessions when subjects were sleepy, but no significant altitude/alcohol interactions on performance (and no hangover effects) were obtained.

To follow up on these results, Collins, Mertens, and Higgins (4) trained subjects to perform on the MTPB in four sessions over a 2-week period. The four sessions were ground level (approximately 1,300 ft) and altitude (12,500 ft) both with and without alcohol (2.2 cc of 100-proof Smirnoff vodka per kg of body weight). Subjects breathed appropriate gas mixtures through oxygen masks at both ground level and altitude. Results showed no differential effect of simulated altitude on breathalyzer readings (peaks averaged .078% at 12,500-ft and .077% at ground level). The best performance occurred at ground level under placebo conditions; the 12,500-ft simulated altitude produced some decrement for the placebo condition scores. Alcohol at ground level resulted in significantly impaired performance during the first three hours after drinking; the addition of altitude to the alcohol condition further depressed performance scores, but to about the same extent that placebo scores were depressed by altitude. Thus, there was no effect of altitude on breathalyzer readings and a simple additive effect of alcohol and altitude decrements on performance scores. Results of the present study, for both age groups, were similar to those noted above except that altitude had no effect at all on either breathalyzer levels or performance.

Finally, in evaluating various types of potential altitude/alcohol effects, it may be useful to consider the possibly different influences associated with (i) acclimitization, (ii) fatigue due to physical exertion at altitude, (iii) durations of exposure, (iv) the sedentary aspects of some conditions (e.g., flying as a passenger) or studies, and (v) altitude/humidity (dehydration) differences between studies.

Altitude. Results from the present study and the other cited alcohol-altitude studies tend to emphasize the potential for interactive effects. However, the data also suggest that altitudes around 12,000 ft provide a narrow margin of safety regarding performance. For example, the present study found no main effect of altitude on complex performance, but the previous study (4) using the same performance equipment yielded decrements due to the simulated altitude. In a different investigation (16), again using the same performance equipment, subjects performed more poorly at altitude vs. ground level when sleep deprived for 24 h; with normal sleep, there was no effect of altitude on their performance. Similarly, in another study (3), tracking performance was adversely affected by altitude vs ground level conditions during midnight tests (when subjects were sleepy) but not during the early evening or in the morning following several hours of sleep. The ground-level "dotting" test scores reported by McFarland and Forbes (15) were also impaired by altitude alone at 12,200 feet.

While it is a truism that effects of any variable on performance will depend on the type of performance test, there is considerable information suggesting that altitudes around 12,000 ft, and perhaps as low as 10,000 ft (5), can produce performance impairment in some healthy subjects. Sleepiness or sleep deprivation seems to potentiate those effects (16). Thus, these data support aeromedical cautions regarding the potential deleterious effects on safety margins of altitudes in the 10,000-12,000 ft range.

CONCLUSIONS

These results and those of related studies suggest that:

1) BAL's are probably not affected by altitudes of 12,000-12,500 ft or less.
2) Altitudes of 12,000-12,500 ft appear to have narrow margins of safety for oxygen-related effects on performance. For some subjects, under some conditions, altitudes of this level produce performance decrements; under other conditions, or for other subjects, decrements may not be evident.
3) Following alcohol ingestion, performance at altitudes of 12,000-12,500 ft may show no change compared with ground level.
4) Performance decrements due to alcohol may be increased by altitudes of 12,000-12,500 ft if subjects are negatively affected by that altitude without alcohol; the combined effects are then simply additive.
5) Alcohol alone does not appear to potentiate performance decrements at altitudes of 12,000-12,500 ft, but sleep loss does.

With respect to the age groups studied, results from this research suggest that:

1) BAL curves do not vary as a function of age group at ground level or at altitude.
[illegible] The detrimental effects of alcohol on performance are greater in the older subjects, especially during the first few hours following drinking.
3) The detrimental effects on performance of the alcohol dosage used disappears within eight hours for both age groups.
[illegible] the age group-alcohol interaction is not affected by altitude.

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